FINAL
Risk Management Recommendations For Quantico Creek

Quantico Marine Corps Base, Quantico, VA

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Risk Management Recommendations For Quantico Creek Quantico Marine Corps Base, Quantico, VA.

A screening-level human health and ecological risk assessment was conducted for Quantico Creek sediments located adjacent to the Quantico Marine Corps Base (hereafter called the Base) by Battelle and Neptune and Company (2002). The screening-level assessments evaluated risk in Quantico Creek sediments to determine if activities at the Base affected the Quantico Creek sediments. The conceptual site model (CSM) identified surface water runoff as the primary transport pathway of chemical constituents from the Base to Quantico Creek. Surface water transport includes non-point source flow during precipitation events, point source discharges from storm sewer outfalls, and surface water flow from Little Creek discharging to Quantico Creek. Several intermittent stream channels and swales receive surface water runoff from the southern ridge adjacent to the floodplain, as well as, runoff generated from the site. Based on the site's shallow topographic gradient, surface water generated at the site will either infiltrate into the underlying substrate or discharge into Little Creek or Quantico Creek via the intermittent stream channels and swales. Groundwater is expected to flow north to north-northeast, most likely discharging into Little Creek or Quantico Creek.

Once in the creek, the primary redistribution of chemical constituents in sediments is due to resuspension and movement of sediments due to storm conditions. Although no specific flow velocity data is available for Quantico Creek, a low flow velocity is expected in Quantico Creek, as demonstrated by the overall shallow nature of the creek and the fact that there are no clear channels running through the lower portion of the creek. Although tidal action could transport chemical constituents in an upstream direction, data indicate that significant transport in this direction has not occurred. Metals associated with upstream mining activities show decreasing concentrations as one moves downstream, and chemical constituents apparently originating from downstream sources (i.e., PAHs, DDxs) have remained localized in downstream sediments. This indicates upstream tidal transport of sediments is not a significant transport pathway. Chemical constituents that have likely originated from downstream sources (i.e., PAHs, PCBs, DDxs), are expected to remain bound to sediment with little partitioning to the water column due to their relatively insoluble nature and their affinity for organic matter. Data collected in the Potomac River just downstream of the mouth of Quantico Creek as part of the Quantico Watershed Pilot Study do not indicate that chemicals from Quantico Creek are being deposited in the near-shore areas of the Potomac River (Battelle and Neptune and Company, 2001).

This paper presents the risk management recommendations for Quantico Creek located adjacent to the Quantico Marine Corps Base, in the context of the risk assessment results and the CSM is presented in the draft document entitled "Quantico Creek Ecological and Human Health Risk Screening Assessment" (Battelle and Neptune and Company, 2002). The following sections summarize the recommended risk management actions.

1.0 Human Health Risks and Risk Management Recommendations

1.1 Direct Contact to Sediment

Potential risk to humans from direct contact with sediments in Quantico Creek was evaluated by comparing maximum concentrations of each constituent in sediment to sediment screening benchmarks accepted by the U.S. Environmental Protection Agency (EPA) Region 3 for evaluating recreational exposure. Only two chemical constituents (arsenic and iron) in Quantico Creek sediments adjacent to the Quantico Marine Corps Base (site sediments) exceeded EPA Region 3 benchmarks for direct contact with sediment in a recreational scenario. Neither of these constituent concentrations was significantly different than sediment concentrations from upstream reference sediments. In fact, both arsenic and iron had higher concentrations in upstream reference sediments than in sediments adjacent to the Quantico Marine Corps Base, suggesting that the likely source of these constituents in Quantico Creek was historical mining activities upstream of the town of Dumfries in present day Prince William Forest Park. No other inorganic or organic constituents exceeded Region 3 risk based concentrations (RBCs) for direct contact with sediment.

Conclusions

- **No incremental increase of risk to humans resulting from direct contact with Quantico Creek sediments as a result of activities associated with Quantico Marine Corps Base.**
- **No Further Management Action is required by the Navy to address Human Health risk posed by direct contact with sediments in Quantico Creek adjacent to the Quantico Marine Corps Base.**

1.2 Human Consumption of Fish – Organic Compounds

Potential risk to humans from consuming fish exposed to Quantico Creek sediments was assessed by comparing estimated maximum fish tissue concentrations to EPA Region 3 RBC values for fish tissue. Estimated maximum fish tissue concentrations were calculated by multiplying the maximum observed sediment concentration by biota-sediment accumulation factors (BSAFs) for fish taken from the EPA National Sediment Quality Survey (EPA, 2001). Using this methodology, polychlorinated biphenyls (PCBs), DDx compounds, dieldrin and several polycyclic aromatic hydrocarbon (PAH) compounds (benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, dibenzo[a,h]anthracene, and indeno[1,2,3-cd]pyrene), were identified as posing potential risk to humans consuming fish based upon the maximum sediment concentrations. With the exception of PCBs, all of these constituents were highest in stations located downstream and adjacent to the Quantico Marine Corps Base, in the vicinity of the confluence of Little Creek and Quantico Creek near the CSX railroad bridge. Distribution of DDx compounds, dieldrin, and PAHs in Quantico Creek suggests the likely source of these compounds is somewhere in the vicinity of Little Creek and the railroad bridge spanning Quantico Creek, although the exact source(s) of these chemicals is unknown. PCBs appear to be relatively uniform in their distribution throughout the lower two-thirds of Quantico Creek, with significantly lower concentrations occurring in the upper third of the creek (Battelle and Neptune and Company, 2002). PCBs are ubiquitous environmental contaminants, and concentrations and distribution of PCBs in Quantico Creek did not indicate any discernible point source at the Quantico Marine Corps Base or elsewhere along Quantico Creek.

Rough estimate or "ballpark" human health risk estimates for the COPCs identified above were calculated for both upstream and downstream areas of Quantico Creek. These risk estimates were calculated at the request of EPA Region 3 during a meeting of the Quantico Subgroup on November 13, 2002 (Alvaro Alvarado, personal communication). The results of these calculations are presented in Appendix A.

1.2.1 Fish Consumption - PAH

Although concentrations of the six PAH compounds (benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, dibenzo[a,h]anthracene, and indeno[1,2,3-cd]pyrene) identified as posing potential risk via ingestion of fish appear elevated in some Base samples compared to upstream samples, the difference is not statistically significantly different from the concentrations observed in upstream reference sediments. The specific source(s) of the PAHs is not known. The only likely source of these constituents at the Quantico Marine Corps Base is non-point source runoff from parking lots and buildings, although there are several non-base related operations that could be contributing PAHs to the creek, including the CSX railroad bridge spanning Quantico Creek and the Possum Point Power Plant on the north shore of Quantico Creek. The distribution of PAH concentrations in Quantico Creek suggests that fish tissue concentrations modeled from maximum up-gradient reference sediment concentrations also exceed Region 3 fish RBCs for all six PAH compounds, and risk calculations performed for both upstream and downstream areas of Quantico Creek showed similar incremental cancer risk for both areas (Appendix A). The use of less conservative exposure point concentrations such as mean and 95%UCL values still result in modeled fish tissue levels greater than RBCs in both site and reference area sediments for five of the six PAHs, with benzo(k)fluoranthene the one exception. This provides possible additional verification that PAH concentrations are a regional issue in Quantico Creek. However, because the highest concentrations are observed in the vicinity of the mouth of Little Creek, this data may be useful to the Base in evaluating non-point source controls for storm water runoff from roadways, parking lots, and buildings.

Conclusions

No Further Management Action is recommended to address potential risk to human health from the six PAHs whose modeled concentrations in fish tissue exceed Region 3 RBCs for the following three reasons:

1) **PAHs in site sediments are not statistically different from the upstream reference area concentrations;**
2) **Reducing site PAH concentrations to minimum reference level concentrations would not significantly reduce the risk to human health (see Appendix A); and,**

3) **No continuing point source(s) of PAHs to Quantico Creek from the Quantico Marine Corps Base is/are apparent as actions have been taken to divert storm water discharges from possible source areas.**

1.2.2 Fish Consumption – PCB

The results of the comparisons of sediment chemical concentrations between background and site conditions in Quantico Creek show that PCB concentrations are significantly higher in downstream sediments than in upstream reference area sediments in Quantico Creek. However, PCB concentrations throughout the lower two-thirds of the creek, including three reference samples located on the north shore, are relatively uniform and do not appear to be indicative of a particular point source to the creek. Fish consumption advisories for PCBs have previously been issued for the region of the Potomac River that includes the mouth of Quantico Creek and for Quantico Creek itself. These advisories recognize a regional PCB problem and are intended as guidelines to limit fish consumption in these areas. When compared to the up-gradient Potomac River confirmation sample collected during the Pilot Study (Battelle and Neptune and Company, 2002), only one Quantico Creek location (AAJ072) had consistently higher concentrations of all the PCB congeners measured compared to the Potomac River reference location sample, with levels at Quantico Creek within a factor of three of the concentrations observed at the Potomac River reference area. This Quantico Creek location is well bounded in all directions by other sample locations that exhibited similar concentrations to those observed in the upstream Potomac River location. Risk calculations performed for both upstream and downstream areas of Quantico Creek showed similar incremental cancer risk due to PCBs in both areas (Appendix A). Although the CSM identified Little Creek as a potential source of chemical constituents from the Base to Quantico Creek, sampling in Little Creek (Tetra Tech NUS [TtNUS], 2001) did not detect any PCB Aroclors, suggesting that Little Creek is not a source of PCBs to Quantico Creek.

Conclusions

No Further Management Action is recommended to address potential PCB risk from consumption of fish exposed to Quantico Creek sediments for the following reasons:

1) **PCB concentrations throughout the lower two thirds of Quantico Creek appear to be representative of regional conditions in this section of the Potomac River;**
2) **Reducing the concentrations of PCBs in the one area where slightly higher concentrations where found would not reduce regional risks to human health for a fish consumption advisory (see Appendix A); and,**
3) **No continuing source of PCBs to Quantico Creek from the Quantico Marine Corps Base (Tetra Tech NUS (TtNUS), 2001) is apparent.**

1.2.3 Fish Consumption – Dieldrin

Regional fish consumption advisories also exist for dieldrin. Dieldrin was elevated in site sediments when compared to both upstream Quantico Creek reference area samples and the Potomac River reference sample. Dieldrin was detected in five of the eight Quantico Creek samples in proximity of the Quantico Marine Corps Base, one of the eight Quantico Creek reference area samples, and in the Potomac River upstream reference sample. The pattern of detected concentrations in the site sediments shows that the highest concentration was observed at near the mouth of Little Creek (AAJ067), with concentrations decreasing quickly away from the shoreline and in a downstream direction. Although no samples were collected immediately upstream, dieldrin was not detected in the nearest upstream samples (AAJ059 and AAJ063), indicating that elevated concentrations of dieldrin are limited spatially to the area immediately surrounding the mouth of Little Creek. Additional sampling in Little Creek (TtNUS 2001) found low levels of dieldrin upstream in the vicinity of Installation Restoration (IR) Site 14, the 1920's landfill, but at levels lower than in Quantico Creek, making it unlikely that this is a continuing source of pesticides to Quantico Creek. As with PAHs, use of reference area sediment concentrations with the literature BSAFs to estimate fish tissue concentrations also results in estimated tissue concentrations exceeding the Region 3 fish RBC levels. Estimated risk calculations showed that incremental cancer risk was in the 10^{-6} range in both the upstream and downstream areas, and Hazard Quotients in both areas were significantly less than 0.1. In addition, the Virginia Department of Environmental Quality (VADEQ) uses an alternative fish tissue screening benchmark of 6.7 μg/kg for dieldrin. Only the maximum observed sediment concentration of 4.32 μg/kg would yield fish tissue concentrations exceeding the VADEQ benchmark. When the 95% upper confidence limit (UCL) on the mean site concentration is used as a more realistic exposure estimator for fish at the Quantico Marine Corps Base, predicted fish tissue concentrations are less than the VADEQ screening level.

Conclusions

No Further Management Action is recommended to address potential human health risk to dieldrin from ingestion of fish exposed to Quantico Creek sediments for the following reasons:

1) **Elevated dieldrin concentrations are spatially limited to the area surrounding the vicinity of Little Creek;**
2) **Estimated risk calculations show no risk from dieldrin in Quantico Creek fish (Appendix A);**
3) **Only use of the maximum observed dieldrin sediment concentration to predict fish tissue concentrations resulted in tissue concentrations exceeding VADEQ screening benchmark for dieldrin. Use of a more realistic estimator of exposure resulted in predicted fish tissue concentrations below the VADEQ screening benchmark.**

1.2.4 Fish Consumption – DDx Compounds

The results of this screening suggest that DDx compounds in sediments may also be of potential human health concern via a fish ingestion exposure pathway. Distribution of DDx compounds in Quantico Creek follow the same pattern as dieldrin, with the maximum observed concentrations near shore around the mouth of Little Creek, and decreasing away from shore and in a downstream direction. Additional sampling in Little Creek (TtNUS 2001) indicated low levels of DDx compounds upstream in the vicinity of IR Site 14, the 1920's landfill, but at levels lower than in Quantico Creek, making it unlikely that this is a continuing source of pesticides to Quantico Creek. Appropriate alternative benchmarks to the Region 3 RBC values for DDx compounds are the VADEQ fish tissue screening benchmarks. Using the VADEQ screening levels in place of Region 3 RBC values, only the maximum observed sediment concentration of DDE would yield fish tissue levels exceeding the VADEQ benchmark. When the 95% upper confidence limit (UCL) on the mean site concentration of DDE is used as a more realistic exposure estimator for fish in Quantico Creek, predicted fish tissue concentrations are less than the VADEQ screening level**.** Risk estimates calculated in Appendix A show that although incremental cancer risk is approximately an order of magnitude higher in downstream sediments than in upstream sediments for DDx compounds, the maximum risk is only in the vicinity of 1×10^{-5} (for DDE).

Conclusions

No Further Management Action is recommended to address potential human health risk to DDx compounds from ingestion of fish exposed to Quantico Creek sediments for the following reasons:

1) **Elevated DDx concentrations are spatially limited to the area surrounding the vicinity of Little Creek;**
2) **Only use of the maximum observed sediment concentration to predict fish tissue levels resulted in tissue levels exceeding VADEQ screening benchmark for DDE. Use of a more realistic estimator of exposure resulted in predicted fish tissue concentrations below the VADEQ screening benchmarks. No maximum predicted fish concentrations of DDD or DDT exceeded VADEQ screening benchmarks for fish tissue.**

1.3 Fish Consumption - Metals

Although comparison of sediment metal concentrations and fish tissue RBC values suggests that the fish ingestion pathway may also be of concern for metals, metals were not identified as chemicals of potential concern (COPCs) from Quantico Marine Corps Base activities for fish ingestion because metals concentrations in site related Quantico Creek sediments were not significantly different from upstream reference concentrations.

Conclusions

- **Concentrations of most metals in Quantico Creek sediments originated from other sources, likely past mining operations unrelated to Quantico Marine Corps Base operations.**

- **Metals concentrations observed in site sediments are not significantly different from concentrations observed in upstream reference sediments.**

Human Health Summary

No Risk Management Actions are warranted for the protection of human health in Quantico Creek from direct contact with creek sediments or from the ingestion of fish exposed to chemical constituents in creek sediments beyond current fish advisory actions already taken by the State of Maryland and the Virginia Department of Health for the Potomac River and its tributaries.

2.0 Ecological Risks and Risk Management Recommendations

Twenty-seven chemical constituents (16 metals, 6 pesticides, 4 PAHs, and total PCBs) had maximum chemical concentrations that exceeded EPA Region 3 sediment ecological screening benchmarks. In addition, 13 metals and one pesticide had hazard quotients (HQs) exceeding "1" in at least one of the food chain exposure models. All of these constituents were carried forward to the ecological screening refinement step (EPA, 1997 and Navy 1999).

In this step, the sixteen remaining metals were eliminated from further consideration as site COPCs because metals concentrations in Quantico Creek sediments located adjacent to the Quantico Marine Corps Base were not significantly different from upstream Quantico Creek reference/background concentrations. Available information indicates that the majority of the metals originated from upstream (non-Base related) sources, in particular historical mining operations located in present day Prince William Forest Park. Site concentrations of alpha-chlordane were not significantly different from upstream reference area concentrations in Quantico Creek, and therefore alpha-chlordane was not retained as a COPC. The 4,4'-DDx compounds in site sediments all were statistically higher in concentration than in upstream reference sediments. Statistical background comparisons could not be conducted for dieldrin or gamma-chlordane because they were not detected in enough of the samples to meet the requirements of the statistical tests, but qualitatively site concentrations of both these constituents appeared higher than background conditions. Dieldrin, gamma-chlordane and the 4,4-DDx compounds were retained for evaluation of exposure point concentrations. PCBs were also retained for further evaluation because of statistically significantly higher concentrations at the site in comparison to the Quantico Creek reference areas. Of the remaining PAHs, benzo(a)anthracene and perylene were eliminated from consideration as COPCs because they were not significantly different from background, while acenaphthene and fluorene were retained for further evaluation based upon results of the background comparisons.

Chemicals not eliminated in the screening process or through evaluation of background conditions were the 4,4'-DDx compounds, dieldrin, gamma-chlordane, total PCBs, acenaphthene, and fluorene. These constituents were next evaluated to determine if their 95% UCL site exposure point concentrations exceeded Region 3 sediment screening benchmarks, and in the case of 4,4'-DDE, whether use of 95% UCL exposure point concentrations in sediment and fish resulted in a food chain dose that exceeded toxicity reference values (TRVs). The 95% UCL exposure point values of all remaining constituents exceeded sediment screening benchmarks. Food chain doses to the great blue heron using 95% UCL concentrations of 4,4'-DDE still resulted in HQ values exceeding "1" (HQ = 4.3).

The screening-level ecological risk assessment and refinement identified the following chemical constituents as COPCs in Quantico Creek sediments adjacent to the Quantico Marine Corps Base: acenaphthene, fluorene, gamma-chlordane, dieldrin, the 4,4'-DDx compounds, and total PCBs. Of these, only the DDx compounds had concentrations in site sediments exceeding effects range-medium (ER-M) thresholds. Given the conservative nature of the screening benchmarks and uncertainties associated with estimates of bioavailability of the chemicals in Quantico Creek sediments, it is difficult to ascertain how much of a risk is posed by the remaining pesticides and the two PAHs in Quantico Creek. This is especially true since all remaining COPCs, with the exception of 4,4'-DDE, have been shown not to be a risk to upper trophic level birds and mammals at the site. The risk management implications and recommendations for each of the remaining ecological COPCs are discussed in the following paragraphs.

2.1 PAHs

Acenaphthene had a maximum observed concentration above the Region 3 ecological sediment screening benchmark near the shoreline (location AAJ072) at the mouth of Little Creek. This is an isolated concentration in that results from locations upstream, downstream, and away from shore did not exceed the Region 3 screening benchmark. Fluorene exceeds Region 3 screening benchmark values at three locations, with the highest concentration at near shore (AAJ072) and concentrations decreasing out from shore and in upstream and downstream directions. Although these two individual PAHs exceeded their respective screening benchmarks, the screening benchmark for Total PAHs was not exceeded at any location. The maximum observed concentrations of both fluorene and acenapthene were below the respective ER-M values for those constituents, and conservative food chain models using maximum observed concentrations showed no risk to piscivores from these constituents in site sediments. As mentioned in the human health risk summary, no known point sources of PAHs to Quantico Creek from the Quantico Marine Corps Base are identified although non-point source runoff from parking lots and buildings in the area may occur, and there are several non-base related operations that could be contributing PAHs to Quantico Creek in this vicinity.

Conclusions

No Risk Management Action is warranted for acenaphthene or fluorene in Quantico Creek sediments for the following reasons:

1) **Extent of contamination is spatially limited to a small area in the vicinity of Little Creek;**
2) **Magnitude of contamination is low, with all concentrations less than the respective ER-M values for acenaphthene and fluorene;**

3) **Total PAHs do not exceed screening benchmarks at any location in Quantico Creek;**
4) **Conservative screening-level food chain models indicate no risk to upper trophic levels from these constituents in Quantico Creek; and**
5) **No continuing point source(s) of PAHs to Quantico Creek from the Quantico Marine Corps Base is apparent.**

2.2 Gamma-Chlordane

Gamma-chlordane was only detected in one sediment location in Quantico Creek (station AAJ067). The location of this detected value is bounded by other samples that have non-detected gamma-chlordane concentrations and are located immediately downstream and offshore, indicating that the spatial extent of contamination is very limited. Likewise, no gamma-chlordane was detected in upstream site-related samples although gamma-chlordane was detected in the furthest upstream reference sample. Although higher than the Region 3 screening benchmark, the detected concentration of gamma-chlordane in the site sediments was lower than the ER-M value, and conservative food chain models using the maximum concentration showed no risk to piscivores from gamma-chlordane in site sediment. Additional sampling in Little Creek (TtNUS 2001) found no evidence of a continuing source of gamma-chlordane to Quantico Creek.

Conclusions

No Risk Management Action is warranted for gamma-chlordane in Quantico Creek sediments for the following reasons:

1) **Extent of contamination is spatially limited to a small area in the vicinity of Little Creek;**
2) **Magnitude of contamination is low, with the single detected concentration less than the ER-M value for gamma-chlordane;**
3) **Conservative screening-level food chain models indicate no risk to upper trophic levels from gamma chlordane in Quantico Creek sediments; and**
4) **No source(s) of gamma-chlordane to Quantico Creek from the Quantico Marine Corps Base is apparent.**

2.3 PCBs

Although a fish consumption advisory is in place for PCBs for human consumption, ecological food chain models indicate that no risk is posed to upper trophic level ecological receptors from PCB concentrations in Quantico Creek sediments or from modeled estimates of PCBs in Quantico Creek fish tissue. PCB concentrations in both site and reference Quantico Creek sediments in the lower two-thirds of Quantico Creek, exceeded Region 3 ecological screening benchmarks, but no sample concentrations exceeded the ER-M value for PCBs. There are no identified point sources of PCBs in Quantico Creek and concentrations in the lower two-thirds of the creek appear to be similar to regional Potomac River PCB levels. Additional sampling in Little Creek (TtNUS 2001) found no evidence that Little Creek is the source of PCBs found in Quantico Creek.

<u>Conclusions</u>
No Risk Management Action is recommended to address potential ecological risk from PCBs in Quantico Creek sediments for the following reasons:

1) **PCBs pose no risk to upper trophic level food chain receptors in Quantico Creek sediments;**
2) **Although most site and creek reference samples in the lower portion of the creek exceed conservative screening benchmarks, the magnitude of exceedance is relatively low, as indicated by the fact that none of the observed concentrations exceed the ER-M value for PCBs;**
3) **Concentrations are fairly uniform across the lower two thirds of Quantico Creek and are likely indicative of regional conditions in the Potomac River; and,**
4) **No continuing source(s) of PCBs to Quantico Creek from the Quantico Marine Corps Base is apparent.**

2.4 DDx

Elevated concentrations of DDx compounds are limited spatially to the area of Quantico Creek surrounding the mouth of Little Creek. Although food chain models suggest potential risk to piscivorous birds from ingestion of 4,4'-DDE in fish tissue, the fact that modeled doses exceed no observed adverse effect level (NOAEL-based TRVs), but not low observed adverse effect level (LOAEL-based TRVs), indicates the magnitude of risk is low. Food chain models indicate that no risk is posed from DDD or DDT in Quantico Creek sediments. Additional sampling in Little Creek (TtNUS 2001) found low levels of DDx compounds in Little Creek sediments in the vicinity of IR Site 14, but at concentrations less than observed in Quantico Creek sediments, suggesting that it is unlikely that Little Creek is a continuing source of DDx compounds to Quantico Creek.

<u>Conclusions</u>
No Risk Management Action is recommended to address potential ecological risk from DDx compounds in Quantico Creek sediments for the following reasons:

1) **Although modeled doses of DDE to piscivorous birds exceeded conservative NOAEL-based TRVs, the magnitude of exceedance is relatively low, as indicated by the fact that modeled doses do not exceed LOAEL-based TRVs;**
2) **Concentrations of DDx compounds exceeding conservative ecological screening benchmarks are spatially limited to the area in the vicinity of the mouth of Little Creek; and**
3) **No continuing source(s) of DDx compounds to Quantico Creek from the Quantico Marine Corps Base is apparent.**

<u>Ecological Summary</u>
No Risk Management Actions are warranted for the protection of ecological receptors in Quantico Creek due to exposure to creek sediments or risks to upper trophic level ecological receptors from the consumption of prey from creek sediments.

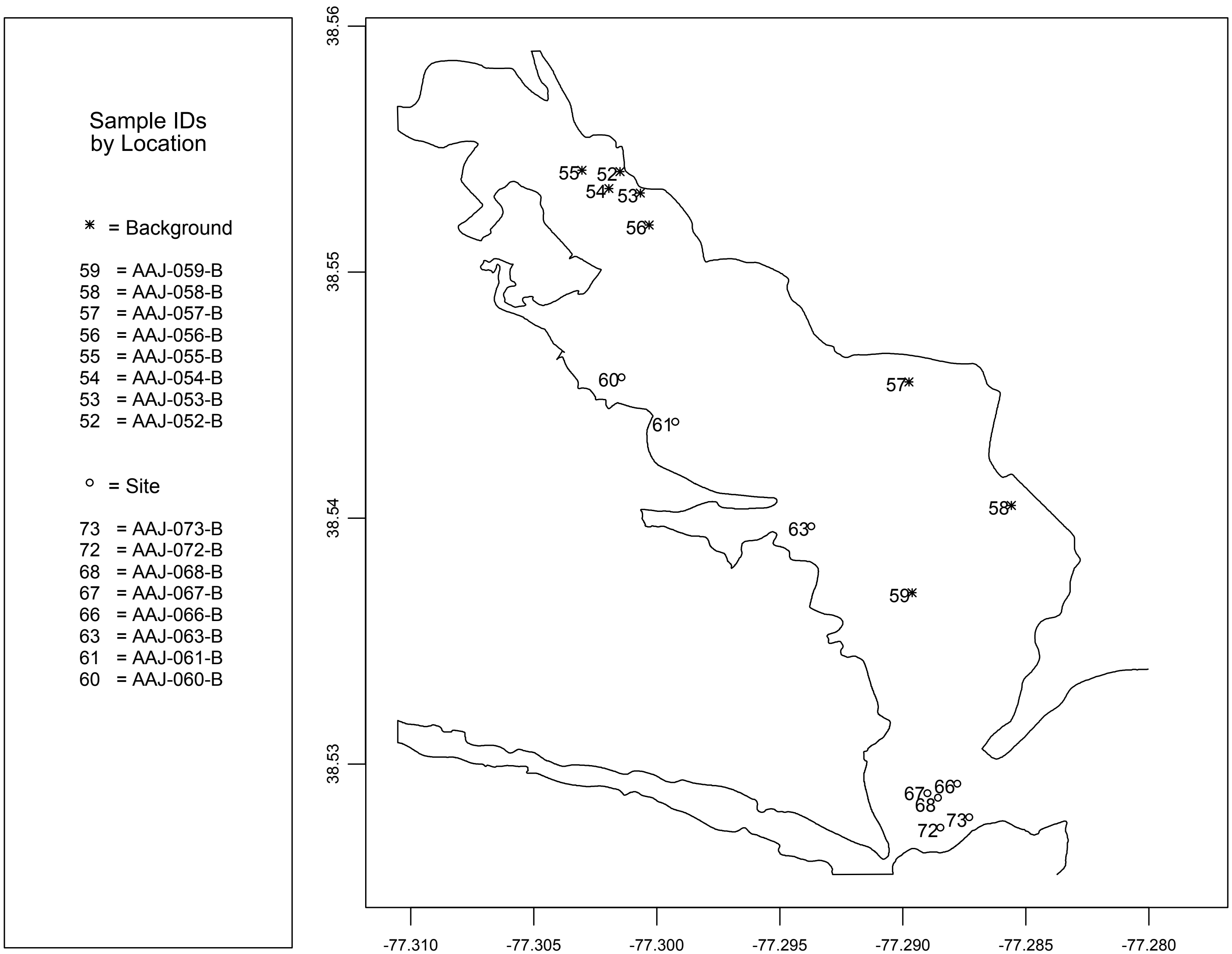

Figure 1. Background and Site Locations and Sample IDs.

APPENDIX A. SUPPLEMENTAL ASSESSMENT OF HUMAN HEALTH RISKS

A-1 INTRODUCTION

This appendix provides a supplemental assessment of human health risks posed by chemical constituents identified as being of potential concern in *Quantico Creek Ecological and Human Health Screening Assessment* (Battelle and Neptune and Company 2002a – hereafter called the Screening Report). This supplemental assessment is intended to provide "ballpark" risk estimates as requested by EPA Region 3 during meetings of the Quantico Subgroup on 13 November 2002 (Alvaro Alvarado, personal communication). The calculations employ reasonable maximum exposure assumptions in order to maintain consistency with exposure assumptions inherent in the risk-based screening criteria used in the Screening Report. Because this assessment is provided as a supplement to a screening-level evaluation and is not intended to comprehensively address uncertainties in potential site risk, calculations related to more likely (central tendency) exposure conditions are not included.

The principal enhancements in this supplemental assessment relative to the screening assessment are the use of site and background area (upstream) data to calculate exposure point concentrations and the explicit evaluation of the relative contribution of background chemical concentrations to site risk. This assessment is limited to evaluating the potential risks related to fish ingestion because this exposure pathway was determined in the Screening Report to be of greater potential significance than direct exposure to contaminated sediments. This assessment is organized as follows:

- Section A-2, the calculation of exposure point concentrations (EPCs) is described and the relative concentrations of chemicals of potential concern (COPCs) in background (upstream) and site sediments are presented.
- Section A-3 provides information on the exposure and toxicity variables, and equations, used in the risk calculations.
- Section A-4 describes the results of the supplemental assessment.

A-2 EXPOSURE POINT CONCENTRATIONS

The EPA recently updated their guidance for EPC calculations that had been originally developed as a supplement to EPA's *Risk Assessment Guidance for Superfund (RAGS), Volume 1 – Human Health Evaluation Manual* (EPA 1989). The updated guidance, *Calculating Exposure Point Concentrations at Hazardous Waste Sites* (EPA 2002b) plus recommendations in the associated software program ProUCL, developed for EPA by Lockheed Martin (EPA 2001), was followed to calculate EPCs for Quantico Creek.

The EPA recommends using the average concentration to represent "a reasonable estimate of the concentration likely to be contacted over time" (EPA 1989) and "because of the uncertainty associated with estimating the true average concentration at a site" recommends that the 95 percent upper confidence limit (UCL) be used. The choice of UCL is based on the distribution of the data with distribution assumptions tested using the Shapiro-Wilk goodness-of-fit test. If the p-value indicates that the untransformed data are not significantly different from normal ($p>0.05$) then the normal distribution is assumed. If the p-value is less than 0.05 then normality is rejected and the following protocol is applied. If the log transformed data are not significantly different from normal ($p>0.05$), then lognormality is assumed; otherwise, lognormality is rejected and a nonparametric (distribution free) UCL is calculated and used.

For normal data, a UCL based on the well-known *t*-statistic was calculated for this assessment. For lognormal data, the Land method using the *H*-statistic is typically used (EPA 2002, Exhibit 3; Gilbert, 1987). However, EPA now recommends an alternative to the *H*-statistic for lognormal data depending on the degree of skewness of the data and sample size (EPA 2002b, Exhibit 7; ProUCL User's Guide Table 1). The alternative is based on the Chebyshev inequality using minimum variance unbiased estimates (MVUE) of the lognormal parameters (EPA 2002b, Exhibits 5 and 6). Therefore, lognormal UCLs calculated for this assessment may use either the *H*-statistic or MVUE approach depending on skewness. If the distribution is neither normal nor lognormal, a nonparametric estimate based on the Chebyshev inequality using the sample mean (arithmetic average) and sample standard deviation was calculated (EPA 2002b, Exhibit 12).

Table A-2.1 provides a simple summary of the upstream and site sediment data including the distribution-dependent estimates of the mean and UCL and the maximum reported concentration. A maximum value shown in brackets indicates that the value is a detection limit. Only chemicals identified as having a potential fish tissue concentration exceeding the fish tissue risk-based concentration in Table 5-1 of the Screening Report are included in Table A-2.1. The UCL value was selected as the EPC except in cases where the UCL exceeded the maximum or there were fewer than 5 detects. In these cases, the maximum concentration was selected.

If a sediment value was reported as "nondetect", the detection limit was used in the EPC calculations. For DDD, DDE, DDT and total PCBs, however, EPC calculations were performed for the sum of two or more isomers. In these cases, nondetect values were assumed to be zero, although in practice most sums were composed of detected values. For normal and nonparametric distributions, the sample mean is listed. For lognormal data, the MVUE estimate of the lognormal mean is given (EPA 2002b, Exhibit 3; R. Gilbert, 'Statistical Methods for Environmental Pollution Monitoring', 1987).

With the exception of alpha chlordane and toxaphene, there is evidence that pesticide concentrations are higher in site sediments compared with upstream sediments. For the PAHs, this was not found to be true. Chemical concentrations in site sediments must be significantly different than in upstream sediments in one or more of four statistical tests in order to conclude that a difference exists.

TABLE A-2.1
EXPOSURE POINT CONCENTRATIONS OF COPCs (µg/kg)

Analyte	Sample size	No. of detects	Mean	UCL	Maximum	EPC	Site > upstream? (a)
Aldrin	8 / 8	0 / 3	0.096 / 0.38	0.12 / 1.8	[0.11] / 1.95	0.11 / 1.95	Yes (b)
Benz(a)anthracene	8 / 8	8 / 8	48 / 113	124 / 183	169 / 298	124 / 183	No
Benzo(a)pyrene	8 / 8	8 / 8	53 / 96	144 / 151	197 / 248	144 / 151	No
Benzo(b)fluoranthene	8 / 8	8 / 8	68 / 123	156 / 186	207 / 278	156 / 186	No
Benzo(k)fluoranthene	8 / 8	8 / 8	68 / 116	169 / 177	228 / 268	169 / 177	No
Chlordane, alpha	8 / 8	8 / 8	0.32 / 0.68	0.40 / 1.92	0.53 / 2.66	0.40 / 1.92	No
Dibenz(a,h)anthracene	8 / 8	8 / 8	7.72 / 13.6	21.5 / 21.7	29.6 / 36.8	21.5 / 21.7	No
Dieldrin	8 / 8	1 / 5	0.17 / 0.81	0.22 / 1.84	0.33 / 4.32	0.33 / 1.84	Yes (b)
DDD (c)	8 / 8	8 / 8	2.11 / 29.6	3.08 / 160	4.76 / 105	3.08 / 160	Yes
DDE (c)	8 / 8	8 / 8	2.11 / 19.3	2.96 / 30.2	4.32 / 44.0	2.96 / 30.2	Yes
DDT (c)	8 / 8	3 / 5	0.35 / 6.61	3.57 / 18.1	1.59 / 22.4	1.59 / 18.1	Yes
Indeno(1,2,3-cd)pyrene	8 / 8	8 / 8	38.3 / 62.1	98.4 / 95.8	134 / 152	98.4 / 95.8	No
PCBs, total (d)	8 / 8	8 / 8	21.1 / 39.8	27.7 / 48.0	35.6 / 65.2	27.7 / 48.0	Yes
Toxaphene	8 / 8	0 / 0	34.0 / 34.4	37.6 / 39.5	[39.5] / [47.9]	39.5 / 47.9	NA

NA: Not applicable; no detected values.
Values are provided according to the convention upstream / site.
Values in brackets [ ] indicate that the maximum value is a detection limit rather than a reported concentration.
(a) Statistical comparison tests to determine whether site concentrations are significantly elevated above upstream concentrations are described in the statistical appendix to the Screening Report.
(b) Detect frequency too low for statistical evaluation.
(c) Twice the sum of individual congeners, as described in Section 4 of the Screening Report.
(d) Sum of 2,4- and 4,4- isomers.

A-3 RISK ASSESSMENT VARIABLES AND CALCULATIONS

Exposure parameter values for calculating risk pertaining to fish ingestion are provided, with references, in Table A-3.1. Rationale for selection of adult and child fish ingestion rate values is provided below.

In the absence of local information on fishing habits and consumption rates of recreational anglers, EPA recommendations for fish ingestion rates for recreational freshwater anglers (Section 10.10.3, EPA 1997b) will be employed in this assessment. A rate of 25 g/day represents the 95th percentile ingestion rate for recreational anglers.

The EPA's recommended fish ingestion rate for recreational freshwater anglers is not specific with respect to demography, but the summaries of key studies supporting their recommendation indicate that it pertains to a general population of adults. Tabulated data for some of the key studies supporting the recommended fish ingestion rate break out age categories of <14 yr, 15-44 yr, and >45 yr, but there is not a clear relationship between these data and EPA's recommendations. However, data for average fish consumption rates in three studies that break out intake according to these age categories (Tables 10-29, 10-35, and 10-37) suggest that fish ingestion rates in the two older age groups are 2-3 times higher than in the <14 yr old group.

TABLE A-3.1. EXPOSURE PARAMETER VALUES

Parameter	Unit	Value	Reference
Freshwater fish ingestion rate (child)	grams/day	8.3	EPA, 1997b
Freshwater fish ingestion rate (adult)	grams/day	25	EPA, 1997b
Exposure duration (child)	year	6	EPA, 1991
Exposure duration (adult, noncarcinogen)	year	30	EPA, 1997c; EPA, 1991 (note 1)
Exposure duration (adult, carcinogen)	year	24	EPA, 1997c; EPA, 1991 (note 1)
Exposure frequency	days/year	365	EPA 1997b (note 2)
Body weight (child)	kilograms	17.4	EPA, 1997a (note 3)
Body weight (adult)	kilograms	71.8	EPA, 1997a (note 4)
Averaging time (carcinogenic effects)	year	75	EPA, 1997a
Averaging time (noncarcinogenic effects)	year	6 (child); 30 (adult)	equal to exposure duration

Notes:
1. 95^{th} percentile of population mobility from 1993 U.S. Census is 30 years, Table 15-176 [for carcinogens, child and adult exposure duration (ED_c and ED_a_carc) are summed to yield 30 years].
2. Fish ingestion rate applies to a one-year period.
3. Mean body weight of male and female children, age 4; Table 7-3.
4. Recommended mean body weight of adult; Section 7.3.

It is likely that fish ingestion rates are minimal for the first year or two within the age range of birth and 6 yrs. For this reason, an assumption was made that the fish ingestion rate for children between the ages of birth and 6 yr was one-third of the 95^{th} percentile value, or 8.3 g/day.

Toxicity values and biota-sediment accumulation factors (BSAFs) are chemical-specific variables that must be defined for the risk calculations. These values are provided in Table A-3.2. Cancer slope factors (SFs) and reference doses (RfDs) were obtained from EPA's online Integrated Risk Information System (IRIS) (EPA 2002c). Additional information on the relative carcinogenicity of PAHs other than benzo(a)pyrene, the only PAH for which IRIS provides a SF, was obtained from the memorandum "*Risk Assessment for PAH Mixtures*" (EPA 1993). A cancer SF represents an upper-bound estimate of carcinogenic potency that relates lifetime average chemical intake to the incremental risk of an individual developing cancer at some time in their lives. An RfD represents a protective estimate of the average daily intake that an individual (possibly a member of a sensitive subpopulation) can tolerate without experiencing systemic health effects. BSAFs were used to relate sediment chemical concentrations to possible fish tissue concentrations. The BSAFs were obtained from the draft EPA report, "*The Incidence and Severity of Sediment Contamination in Surface Waters of the United States, National Sediment Quality Survey: Second Edition*" (EPA 2001b).

TABLE A-3.2
TOXICITY AND BSAF VALUES

Analyte	*Oral SF* (kg-d/mg)	*Oral RfD* (mg/kg-d)	*BSAF*
Aldrin	*17*	*3.0E-05*	*1.8*
Benz(a)anthracene	*0.73*	*NA*	*0.29*
Benzo(a)pyrene	*7.3*	*NA*	*0.29*
Benzo(b)fluoranthene	*0.73*	*NA*	*0.29*
Benzo(k)fluoranthene	*0.073*	*NA*	*0.29*
Chlordane, alpha	*0.35*	*5.0E-04*	*4.77*
Dibenz(a,h)anthracene	*7.3*	*NA*	*0.29*
Dieldrin	*16*	*5.0E-05*	*1.8*
DDD	*0.24*	*NA*	0.28
DDE	*0.34*	*NA*	7.7
DDT	*0.34*	*5.0E-04*	1.67
Indeno(1,2,3-cd)pyrene	*0.73*	*NA*	*0.29*
PCBs, total	*2.0*	*NA*	*1.85*
Toxaphene	*1.1*	*NA*	*1.8*

NA: not available

A-4 RISK ASSESSMENT RESULTS AND CONCLUSIONS

Incremental cancer risks (ICR) were calculated assuming six years of exposure with characteristics of a child followed by 24 years of adult exposure. The following equation was used to calculate ICR:

$$ICR = \frac{C_{s,i} \times BSAF_i \times \left[\left(IR_{f,a} \times EF_a \times ED_a \big/ BW_a \right) + \left(IR_{f,c} \times EF_c \times ED_c \big/ BW_c \right) \right] \times SF_{ing,i} \times 10^{-6}\ kg-mg / g-\mu g}{AT_{carc}}$$

where, $C_{s,i}$ = concentration of contaminant i in sediment (µg/kg sediment);
$BSAF_i$ = biota-sediment accumulation factor, contaminant i (µg/kg fish per µg/kg sediment)
$IR_{f,c}$ = child fish ingestion rate (g of fish/d);
EF_c = child exposure frequency (d/y);
ED_c = child exposure duration (y);
BW_c = child body weight (kg);
$IR_{f,a}$ = adult fish ingestion rate (g of fish/d);
EF_a = adult exposure frequency (d/y);
ED_a = adult exposure duration (y);
BW_a = adult body weight (kg);
$SF_{ing,i}$ = ingestion slope factor, contaminant i $(mg/kg\text{-}d)^{-1}$, and,
AT_{carc} = averaging time for carcinogenic effects (d).

Chemical hazard quotients (HQ) were calculated separately for adults and children. The following equation was used to calculate HQ:

$$HQ = \frac{C_{s,i} \times BSAF_i \times IR_f \times EF \times ED \times 10^{-6}\ kg - mg/g - \mu g}{BW \times AT_{nc} \times RfD_{ing,i}}$$

where, $C_{s,i}$ = concentration of contaminant i in sediment (µg/kg sediment);
$BSAF_i$ = biota-sediment accumulation factor, contaminant i (µg/kg fish per µg/kg sediment)
IR_s = fish ingestion rate (g of fish/d);
EF = exposure frequency (d/y);
ED = exposure duration (y);
BW = body weight (kg);
AT_{nc} = averaging time for noncarcinogenic effects (d); and,
$RfD_{ing,i}$ = ingestion reference dose, contaminant i (mg/kg-d).

Chemical-specific ICRs and HQs are shown in Table A-4.1. At the base of the table, ICR values are summed across chemicals to produce a total ICR for upstream and site sediments. Hazard quotient values are also summed to generate a hazard index for all chemicals. This is a protective approach to calculating a hazard index because it does not distinguish the potentially different target organs and critical effects among the chemicals. Sums are provided for all chemicals shown in Table A-2.1 as well as for just those chemicals where site sediment concentrations are statistically greater than upstream concentrations. The HQs for both site and upstream areas are well below a threshold of one. Incremental cancer risk values range between approximately 1×10^{-5} and 1×10^{-4}. The ICR summed across all COPCs is identical between site and upstream areas, whereas the ICR related only to chemicals that had significantly higher concentrations in site sediments differs (this refers to chemicals where the entry in the last column in Table A-2.1 is "Yes"). The reason for this is that ICR values are most affected by PAH concentrations, which were found to be consistent between site and upstream sediments.

The distinction between site chemicals and all chemicals is based on the result of statistical comparison tests described in Appendix A of the Screening Report. Although statistical differences between site and upstream PAH concentrations were not found to be significant, this conclusion is based on relatively small sample sizes of eight samples per group. As evident in the PAH plots in Appendix A of the Screening Report, there is also evidence that PAH concentrations in the site data set are higher in sediments near the mouth of Quantico Creek than in the samples collected adjacent to the base. Therefore, the conclusion from statistical tests that PAH concentrations in site sediments are indistinguishable from upstream sediments should not be interpreted as definitive. It follows that distinctions between results of all chemicals and just site chemicals are likewise subject to uncertainty.

TABLE A-4.1
CHEMICAL CANCER RISKS AND HAZARDS FOR FISH INGESTION

	UPSTREAM			SITE		
Analyte	ICR	Adult HQ	Child HQ	ICR	Adult HQ	Child HQ
Aldrin	5.0E-07	0.002	0.003	8.9E-06	0.04	0.06
Benz(a)anthracene	3.9E-06	NA	NA	5.8E-06	NA	NA
Benzo(a)pyrene	4.6E-05	NA	NA	4.8E-05	NA	NA
Benzo(b)fluoranthene	4.9E-06	NA	NA	5.9E-06	NA	NA
Benzo(k)fluoranthene	5.3E-07	NA	NA	5.6E-07	NA	NA
Chlordane, alpha	1.0E-07	0.001	0.002	4.8E-07	0.01	0.01
Dibenz(a,h)anthracene	6.8E-06	NA	NA	6.9E-06	NA	NA
Dieldrin	1.4E-06	0.004	0.006	7.9E-06	0.02	0.03
DDD	3.1E-08	NA	NA	1.6E-06	NA	NA
DDE	1.2E-06	NA	NA	1.2E-05	NA	NA
DDT	1.3E-07	0.002	0.003	1.5E-06	0.02	0.03
Indeno(1,2,3-cd)pyrene	3.1E-06	NA	NA	3.0E-06	NA	NA
PCBs, total	1.5E-05	NA	NA	2.7E-05	NA	NA
Toxaphene	1.2E-05	NA	NA	1.4E-05	NA	NA
SUM, total	**1E-04**	**0.01**	**0.01**	**1E-04**	**0.1**	**0.1**
SUM, site chemicals	**2E-05**	**0.008**	**0.01**	**6E-05**	**0.1**	**0.1**

NA = Not applicable.

The results of this assessment of potential risks related to fish ingestion support the conclusions of the human health screening assessment (Battelle and Neptune and Company, 2002). While ICR related to fish ingestion may be of concern, it is evident that the relative risk between site and upstream areas is largely indistinguishable. Factors such as the range and feeding characteristics of different fish species, and the habits of local anglers, are also likely to play a role in establishing actual fish tissue chemical concentrations and/or associated cancer risks.

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